Evaluation of modelled spatially distributed predictions of soil erosion by water versus field-based assessments

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Abstract

Policy makers concerned about soil erosion and its impacts need good quality information on which to base their decisions. There is a trend toward using erosion models to aid such decision making. Such models are based on data obtained from experimental plots. The theoretical results need to be compared with information gained from monitoring erosion in the field to assess if theory accords with reality. Data from the Minimum Information Requirement version of the Water Erosion Prediction Project model (MIRSED) are compared to information gained from field monitoring over a five year period (1982-86) in 11 localities widely spread throughout England and Wales. Two of the localities, Gwent and Shropshire, are examined in detail. The model seriously over predicts erosion, both in amount and extent. Also, the statistical distributions of the data values are different. The model predicts erosion will happen where it does not. The reasons why the two assessments of erosion differ greatly are explored. This comparison shows there is an urgent need to develop models which incorporate information gained from field-based observations. Until better models are devised policy makers and decision takers should treat the results of modelling exercises with great caution.

Keywords: Soil erosion; Policy decisions; MIRSED model; Field-based assessment

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Introduction

There is a trend for Government Departments, led by the United States Department of Agriculture (Committee on Conservation Needs and Opportunities (CCNO), 1986), now followed by European Governments (Department for Environment, Food and Rural Affairs (DEFRA), 2004) the European Commission (Van der Knijff et al., 2000; Jones et al., 2004) and their Agencies (Gobin et al., 2003; Environment Agency (EA), 2004) to use models as indicators to predict and assess erosion in order to help make policy decisions. This approach is attractive because modelling has become easier and quicker as large datasets from experimental plots can be manipulated by powerful computers (Boardman, 1996) and incorporated into Geographical Information Systems (De Roo et al., 1998). Presently, there is a debate under way about which indicators should be used for assessing and monitoring soil erosion by water across Europe (Gobin et al., 2004). A process modelling approach is recommended, and the Pan European Soil Erosion Risk Assesment (PESERA) model is promoted but it has its anomalies and limitations (Kirkby et al., 2004). Model results can be compared to select the most appropriate model

(Favis-Mortlock et al., 1996; Favis-Mortlock, 1998). However, the models used are based on results obtained from plot experiments and have not been validated nor compared with assessments of erosion made at the field scale. Models should generate data which replicates what happens in the field with regard to the extent and severity of erosion (Evans, 1998). There is information available in England and Wales to make comparisons between data obtained by modelling erosion and that obtained by field monitoring. It is probably only in Britain that such comparisons can be made, yet few (if any) models have been rigorously evaluated in the light of such data, which is seen to be a crucial step towards improving erosion predictions in the UK (Brazier, 2004).

In the 1990s a model was devised to predict hillslope soil erosion in England and Wales (Brazier et al., 2001a; Brazier et al., 2001b). A Minimum Information Requirement version (MIRSED) of the Water Erosion Prediction Project (WEPP) hillslope model (Nearing et al., 1989) was used. The model will only be briefly described here; it is described in more detail elsewhere (Brazier et al, 2000; Brazier et al 2001a; Brazier et al 2001b). Initial comparisons of the model output were made with, among other sources of information, the rates of erosion obtained over a three year period (1982-84) by the Soil Survey of England and Wales (SSEW)/Ministry of Agriculture, Fisheries and Food (MAFF) Erosion Monitoring Programme (Evans, 1988). However, no attempt was made to relate the spatial distribution of the rates of erosion predicted for 1 km^2 grid cells with the distribution of channel (rill and gully) erosion as mapped in the field.

It is accepted here that predicted rates may not relate accurately to those assessed in the field for in the field only channel (= rill, ephemeral gully and gully) erosion was recorded whereas WEPP includes splash, sheet and rill erosion. The likely overestimate of erosion by models based on experimental plot data such as the Universal Soil Loss Equation (USLE) is discussed elsewhere (Evans, 1990a, 1993a, 1995, 2002; Boardman 1998a). WEPP too is based on plot data. However, the relative differences in amounts eroded, for predicted erosion and for erosion assessed in the field, should be similar, for example soils with high silt and fine sand content should have higher erosion rates than sandy or, especially, clayey soils or the erosion rates in different crops should have similar relative differences. For example, Evans (1995) found that the relativities between amounts eroded in different crops were similar for both plot experiments and field assessments.

There are two aspects which need to be taken into account when assessing erosion. However, generally only one, rate of erosion, is considered. The other aspect, the distribution and extent of erosion within the landscape is rarely considered except by those assessing erosion in the field (Alstrom and Akerman, 1992; Auzet et al., 1993; Boardman, 1990, 2003; Evans, 1981, 2002; Govers, 1991; Vandaele and Poesen 1995), although Jones et al. (2004, pp.32) note that " The area affected by erosion is the key indicator for soil erosion". This is because, presumably, it is considered by modellers, especially those using a USLE based model or similar, that erosion occurs across the whole of the landscape. That may be so for sheet erosion, as flow over vegetated surfaces can take place, although erosion rates are likely to be very low in humid climates even on very erodible soils with high fine sand/coarse silt contents. Channel erosion does not take place across the landscape, it only occurs where soils are bare of vegetation.

As noted above the MIRSED-WEPP model depicts sheet and channel erosion whereas the field assessment is of channel erosion only. However, it would be expected that where higher rates of erosion are predicted by the model we should find widespread erosion in the field. Conversely, where high rates of erosion have been measured in the field and where erosion was found to be extensive, these findings should be mirrored by the predictions even if the predicted rates of erosion are different.

Here, we compare both erosion rates and the distribution within the landscape of those rates, as averaged over 1km^2 cells as predicted by the MIRSED-WEPP model, with estimates of channel erosion and the distribution of eroded fields as mapped in the same landscapes. In other words, prediction versus what might be termed 'reality'.

We will briefly describe the MIRSED-WEPP model, its findings in relation to 11 localities in lowland England and Wales where erosion was assessed in the field (Figure 1), and then examine and compare in more detail the results from just two landscapes, one of dominantly sandy soils in Shropshire, the West Midlands of England in contrast to a landscape with mostly fine loamy (clay loam and silty clay loam) soils in Gwent, south east Wales. Based on these comparisons we will then draw some conclusions as to the effectiveness of the model in assessing erosion in lowland England and Wales as well as drawing some wider conclusions about the performance of spatially distributed models against observed soil erosion datasets in general.

The MIRSED-WEPP model

It is a complex model of a WEPP hillslope which produces output for all soil, slope and land use combinations that occur in the modelled landscape. The data are held within a Geographical Information System framework and are used to parameterise the WEPP model for all hillslopes within each 1km^2 grid cell across a landscape. Using a representative time series of climate data, mean runoff and soil erosion are simulated for all the hillslopes occurring in the grid cells. Thus, the complex input requirements of WEPP are subsumed within the model to produce easily assimilated information in the form of a map showing the potential hillslope erosion for each grid cell (Figure 2).

The model differs from the scale-sensitive modelling of projects such as MEDALUS (Kirkby et al., 1996, 1998), which take into account different dominant processes at different scales. No attempt is made to truly 'upscale' from the hillslope scale to the catchment or region, rather it is recognised that hillslope scale erosion will occur under a variety of scenarios at different magnitudes, the simulated results of which are mapped out to the sites in question. The MIRSED-WEPP model also differs from other established methodologies such as the 'erotop' approach of Kertesz and Markus (1995). The latter approach applies the USLE to all hillslopes that occur within an area, and is consequently less computationally efficient than the MIRSED-WEPP model which may model widespread hillslope types once only, but use the results numerous times. Further discussion of the modelling approach used here is made in Brazier et al. (2001a).

The model was used to predict mean rates of hillslope erosion in 1km^2 grid cells in 11 localities widely spread throughout central and southern England and Wales (Figure 1). The localities are selected from the 17 areas monitored in the mid-1980s as part of the SSEW/MAFF project to assess the magnitude and extent of the erosion problem in England and Wales (Evans, 1988).

Field assessment of erosion

Between 1982 and 1986 air photos, mostly at a scale of 1:10,000, were taken each year in spring or early summer, weather permitting, of 17 strips of land located in England and Wales to sample a great variety of soil landscapes. The air photos were interpreted to locate channel (= rill, ephemeral gully and gully) erosion and deposition and field checking was carried out in late summer and early autumn to assess if the photo-interpretation was correct, to identify other eroded fields, and to estimate volumes eroded. This was done by estimating channel cross-section areas and lengths within a field and/or by estimating the volume of soil contained in deposits. The volumetric measure is converted to a one of mass by multiplying by 1.3, the assumed dry bulk density of the eroded topsoil (g cm^{-3} or t m^{-3}). More detailed descriptions of the monitoring project are given in Evans (1988, 1993b, 2002). The results from the first three years of the study are given in Evans (1988), and are those which are used in the earlier papers which describe the MIRSED-WEPP model (Brazier et al., 2001a, 2001b). The results from the full five years of the study (Evans, 1993b, 2002) are given here.

Prediction versus reality - a general comparison

The predicted erosion rates for the grid cells in these localities are shown in Figure 2. Erosion appears most widespread and most severe in Gwent, Herefordshire and Dorset and least in Cambridgeshire/Bedfordshire. An examination of topographic maps shows that predicted erosion rates are highest where relief is greatest and slopes are often steep. Generally, rates are also higher where rainfall is higher (Table 1). In some localities it is not easy to relate the spatial distribution of erosion rates to topography, land use or the different soil associations (SSEW, 1983) lying within the localities, or a combination of these.

The mean predicted amounts eroded per year for the localities can be estimated. This crude exercise was done by assigning to each grid cell a value equal to the midpoint of the MIRSED-WEPP output classes (Figure 2) for the four lowest classes, (ie 0.25, 0.75, 1.5 and 3 t ha^{-1} yr^{-1}) and for the highest class assigning a conservative value of 5 t ha^{-1} yr^{-1}, summing up the values and dividing by the total number of cells (Table 1). The field estimate was derived by dividing the total amount of erosion (t) in the transect over the five year period by the area (ha) of agricultural land.

The predicted amounts do not relate well to the field estimates (Table 1). The ratios of the field-based values to those predicted by the model vary from 1:2.5 to 1:161. Where they relate best, Nottinghamshire (1:2.5), Shropshire (1:3) and Staffordshire (1:3) the field estimates of mean erosion per farmers' field are on the high side (Table 2) but the area of land covered by eroded fields is large relative to the other localities (Table 1). The soils in these localities are dominantly sandy. Other ratios of 1:10 or less are found in those localities where erosion rates were high (Kent 1:10; Somerset 1:4) but the extent of erosion was low or rates were lower but eroded fields were more extensive (Norfolk East 1:8; Sussex 1:9). In Kent and Somerset soils are silty but topography and land use inhibit the extent of erosion. In Norfolk and Sussex soils are sandy and stony silty soils respectively, but arable land use and topography facilitate the occurrence of channel erosion. Higher ratios are found where soils are more resistant to erosion and erosion was not extensive. In Cambridgeshire/Bedfordshire (ratio 1:34), soils are clayey and slopes are often gentle, though cultivated land is extensive. In Dorset (1:44) soils are often clayey and much land is under grass for grazing animals as it is in Gwent (1:64) and Herefordshire (1:161).

It may be that some of the differences in erosion rate values between the two approaches can be explained by the differences in area over which the assessments were made, for the model predicted erosion for a larger area than was monitored on the ground. Thus, the air photos taken each year for the monitoring project did not always exactly follow the same flight line nor were the photos taken from the same height above ground level and so did not always cover exactly the same area of ground.

Prediction versus reality - a more detailed comparison

In view of the poor relationships described in the above paragraphs we looked in more detail at two localities to try to evaluate further the reasons for the poor depictions of erosion by the model. The two localities, Gwent and Shropshire, cover similar extents in area (Figure 3) but topography, soils and land use are very different and Gwent receives more rainfall (Table 1).

In Gwent, the north-south study area passes in the north from undulating land flanking the River Trothy, on Devonian silty shale, siltstone and sandstone, with a relief of about 50m, to the more deeply dissected rolling country with narrow interfluves on Devonian sandstone. Much of the transect falls within this landscape. The rolling landscape terminates to the south in a high escarpment reaching to over 260m above sea level. The soils are reddish, and of medium textures but silty in the north with occasional patches of clayey till, generally on lower ground. Land use was dominantly pastoral, but with occasional fields of winter cereals and rarely potatoes. Woods are not uncommon but in the 1980s were still being converted to grassland. Land use will have changed little since the mid-1980s.

In Shropshire, again a north-south transect, in the north of the study area slopes rise steeply from the incised floor of the meandering River Worfe at about 45m above sea level to wide gently sloping crests at about 100m altitude. To the south of the Worfe is a series of ridges rising to about 140m, often with strongly and steeply sloping escarpments and valley sides. Soils are mostly sandy, on soft Permian sandstone under the ridges and on lower ground on glaciofluvial drift, with medium loams on patches of till which occur occasionally. All the soils are vulnerable to erosion. Except for grassland on the steep slopes much of the land was cultivated and a wide range of crops grown, including winter and spring cereals, sugar beet, potatoes and market garden crops. These latter crops were often grown with irrigation, especially in and around the Morfe valley in the south of the transect. Since the mid-1980s some of the cropped land has gone under grass, much of it as a golf course, and cereals are grown more in the Worfe valley than they were.

The average area covered each year by the air photos was 36.7km^2 in Gwent and 31.1km^2 in Shropshire. However, the 'core areas' photographed each year are smaller (Figure 3) and approximate to about 24km^2.

Over the 5 year period, in Gwent, channel erosion occurred in 74 fields, primarily in winter cereals (54%), newly sown ley grasses (23%) and spring cereals (19%) whereas in Shropshire erosion occurred in 197 fields and in a much wider range of crops (sugar beet - 30%; winter cereals - 21%; potatoes - 18%; spring cereals - 11%; field vegetables - 8%; ley grassland - 6%; as well as other crops). Cereals erode much less severely than most other crops and are much less at risk of erosion (Evans, 2002).

According to the model erosion would be expected to be much more extensive in Gwent than in Shropshire (Figure 2) and rates of erosion higher. This is not so (Figure 3 and Table 1). In the 'core areas' photographed each year, on average 14.6 fields eroded in Gwent and 37.8 in Shropshire.

Predicted amounts eroded were estimated for the two localities for the 24 1 km squares of the 'core areas'. Amounts eroded (t ha^{-1} yr^{-1}) were assigned as described above and the values summed for the 2,400ha. The sum totals are compared with the amounts of soil eroded in the fields within the 'core areas'.

Predicted erosion for the Gwent transect is 6222.5 t yr^{-1}, three times **more** than for Shropshire (2075.0 t yr^{-1}). Actual erosion is estimated to be 30.2 t yr^{-1} in Gwent, 4.6 times **less** than the amount (139.1 t yr^{-1}) in Shropshire. Prediction does not square with reality therefore. The amounts predicted to have eroded are far too high, from 15 times more for Shropshire to 206 times for Gwent. Far more serious, however, is the fact that reality is the reverse of what is predicted, ie that erosion is more severe and extensive in Shropshire than it is in Gwent.

It appears that topographic and rainfall factors drive the MIRSED-WEPP model, more than land use and soils. Though the combination of all of these factors is considered within the MIRSED approach, it seems that the balance between these factors is not described well for the sites used in this comparison. For the UK, topographic and rainfall drivers are not the most appropriate factors. For there to be much erosion in lowland England and Wales soils have to be exposed to rain by cultivation. The proportion of arable land within a soil association is a pointer to how extensive erosion is likely to be in that association and was the main basis for Evans' (1990b) classification of soil associations at risk of erosion. That classification was based on the information gained from the SSEW/MAFF monitoring project. A soil's topsoil texture is an indication mainly of the likely severity of erosion, but it is only when those soils are largely under cultivation that erosion will be both extensive and severe if slopes are generally steeper than 3^o (5%). Thus, from the descriptions of the land use of the soil associations occurring in the two localities (Table 3) it would be expected that erosion would be less likely to be extensive in the soil association found in the 'core area' of the Gwent study area than those in Shropshire. Also, the topsoil texture of the Milford association, clay loam (Rudeforth et al., 1984), which underlies the 'core area' in Gwent is less vulnerable to channel erosion than is the sandy loam (Salwick association) and sandy (Bridgnorth and Newport 1 associations) topsoil textures found in Shropshire (Ragg et al., 1984). This is borne out by the mean erosion rates of the associations (Table 4).

Furthermore, the model appears not to take into sufficient account that some arable crops and soils are more vulnerable to erosion than others and that the timing of planting and harvesting of the crop are important. Thus, erosion is more likely to occur when the soil is saturated and the surface is smooth around the time the crop is drilled or after crops have been harvested under wet conditions.

Two more comparisons can be made between the results predicted by the model and what is found in the field. The first compares the statistical distribution of the values of the erosion rates obtained by the two methods (Table 5). Although not strictly comparing like with like, intuitively they should have some similarity. They do not. What is especially noteworthy is that, unlike the field values, the statistical distribution of the model values are not positively skewed, as they are in other field-based assessments of erosion (Boardman 1996; Evans, 1998 and 2002; Boardman, Favis-Mortlock, 1999) and from aggregated plot-based models (Edwards, 1987; Evans 1995; Favis-Mortlock, 1998; Boardman, Favis-Mortlock, 1999). This is perhaps due to the inclusion of sheetwash erosion in the predicted results as being far more widespread in the landscape than it is in reality, a disparity that is further exaggerated as the field observations did not consider the relatively low (but potentially widespread) rates of interrill processes as they were, at that time, considered of insignificant impact. Evidence suggests (Evans, 1990a, in press) that in lowland England and Wales the amounts transported by sheet wash are small (0.1-0.3 t ha^{-1} yr^{-1}) and, although important in terms of polluting water courses, are not important in terms of lowering the land surface.

The second comparison relates to where in the landscape erosion is taking place. The model predicts erosion on hillslopes, as this is what it was designed to do. However, in Gwent most erosion takes place in dry valley floors and depressions, 71.2% of all eroded fields. Only 15.2% of erosion was located on slopes; the remainder occurred both on slopes and depressions within the same field. In Shropshire, erosion dominantly takes place on slopes (48.4%) and much less only in valley floors and depressions (25.0%). Erosion along dry valley floors is found widely throughout England and Wales, especially on heavier textured soils and in winter cereal fields (Evans, 1993, 2002).

Hillslope-based models are driven by rainfall intensity which assumes runoff and erosion take place only when rainfall exceeds infiltration capacity in unsaturated soils (Hortonian flow). Such a model probably only applies to fields in England and Wales sown to crops in late spring and summer. It probably does not apply to runoff and erosion which take place when low intensity rains fall onto saturated soils in winter and early spring. Kwaad (1998) makes a similar point for soils in Limburg. This is also a general problem for the majority of spatially distributed erosion models as they rarely consider the generation of overland flow from both infiltration and saturation excess mechanisms, assuming them to be initially exclusive within a hillslope. This is clearly not the case and will continue to be a limitation for erosion modelling in the UK if both processes are not adequately included in process-based models. Consequently, this would seem to be the main downfall of the modelling approach adopted; it is not truly describing the type of erosion that is being observed. It is suggested that this is a common problem with all spatially distributed models of erosion, as they do not predict the wide range of erosion processes that contribute to observed rates.

Furthermore, previous work with the WEPP model (Brazier et al., 2000) demonstrates the significant uncertainty or range of error that surrounds predictions. When predictions are mapped-out spatially, as is the case for the results presented here, this uncertainty remains. Given these levels of uncertainty, which may be endemic through all similar process-based erosion models, it is of little surprise that results from such models perform poorly against detailed observed data.

There is a great need to integrate the work of modellers with that of researchers assessing erosion in the field (Boardman, 1998b; Brazier, 2004). In that way theory and reality, as reflected in assessments of potential and actual erosion, are brought together. Though this paper provides a somewhat negative demonstration of this approach, in that model predictions are shown to be erroneous when closely scrutinized against observed data, the approach must be pursued further if progress is to be made in linking soil erosion predictions with soil erosion observations.

Conclusions

The MIRSED-WEPP model does not relate well to what is seen in the field in lowland England and Wales; theory does not reflect 'reality'. The major drivers of the model appear to be rainfall and topographic factors with less emphasis being placed on the role of land use and soils. Consequently, as in lowland England it is land use and soil factors which control the extent and severity of erosion, predictions fail to match observations adequately.

The model assumes that erosion takes place across the landscape. Sheet wash may, but channel (rill, ephemeral gully, gully) erosion does not. However, the model does consider sheetwash to be important, perhaps because it was developed from plots in the USA that do show high rates of sheetwash erosion, so this is an area that must be addressed by ongoing erosion prediction work if improvements in predictions are to be made.

Rates of erosion are not predicted well. They are always too high and only appear to be of the right order where channel erosion is extensive, i.e. they give the right answer for the wrong reason. This, again, reflects the lack of agreement between the types of erosion that are predicted and those that are observed. So it is perhaps not surprising that this is the only (apparently) real area of agreement, albeit still poor, between the predictions and the observations.

If erosion was occurring at the rates predicted by the model it would dominantly be channel erosion, and the evidence for erosion and its impacts would be clearly seen in the landscape, in the form of many more rilled and gullied fields with prominent large depositional zones and severe impacts on water courses. Such impacts are not seen.

Hence, a model driven by rainfall erosivity and unproven relationships between slope angle and severity of erosion is not appropriate for predicting erosion in lowland England and Wales. This comment also applies, for example, to USLE based models used to assess erosion risk in Europe (Van der Knijff et al., 2000; Jones et al, 2004).

A hillslope-based model may not be appropriate for predicting erosion in England and Wales on other grounds too. It is a model which predicts erosion only for hillslopes and assumes runoff and erosion take place only when rainfall exceeds infiltration capacity in unsaturated soils (Hortonian flow).

If models are to be used to predict erosion in order to help policy makers make their decisions, the models should incorporate, and certainly be validated by, field-based assessments of erosion (Gobin *et al.,* 2004).

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Table 1 Estimates of mean erosion (t ha^{-1} yr^{-1}) for five years for 11 monitored localities, estimated rainfall (mm)[a] and area (%) agricultural land covered by channel eroded fields

Locality	Predicted erosion	Field estimate	Ratio of field :prediction	Estimated rainfall	Area covered

Gwent	2.80	0.044	1:63.6	900-1000	2.45
Herefordshire	2.57	0.016	1:160.6	675-700	1.87
Dorset	2.53	0.058	1:43.6	800	2.75
Sussex	0.92	0.107	1:8.6	820-950	6.70
Shropshire	0.91	0.330	1:2.8	690	9.19
Norfolk East	0.89	0.114	1:7.8	690-710	8.29
Somerset	0.84	0.222	1:3.8	800	4.08
Kent	0.83	0.082	1:10.1	670	1.89
Staffs	0.67	0.214	1:3.1	675	6.40
Nottinghamshire	0.61	0.246	1:2.5	620-730	9.01
Camb/Beds[b]	0.44	0.013	1:33.8	580-630	2.01

[a] Rainfall estimated from maps in SSEW Bulletins 11-15, 1984

[b] Cambridgeshire/Bedfordshire

Table 2 Mean rate of erosion (t ha^{-1}) per field for 11 localities monitored between 1982-1986

Locality	Mean rate	Number fields

Kent	6.27	41
Somerset	6.10	161
Staffordshire	3.16	205
Shropshire	3.07	197
Nottinghamshire	1.94	209
Gwent	1.86	73
Dorset	1.76	92
Herefordshire	1.56	89
Norfolk East	1.34	118
Sussex	1.04	62
Camb/Beds	0.61	65

Table 3 Land use description of the dominant soil associations found in the Gwent and Shropshire study areas - after Mackney *et al.*, 1983

Locality	Soil association	Land use

Gwent	Milford	Dairying, some cereals, coniferous woodland on on steep slopes
Shropshire	Bridgnorth	Cereals and potatoes, horticultural and fruit crops; Some permanent grassland and woodland on steep slopes.
	Newport 1	Cereals, sugar beet and potatoes
	Salwick	Cereals, sugar beet and potatoes, some short term grassland

Table 4 Erosion rates (t ha^{-1} yr^{-1}) of the main soil associations found in Gwent and Shropshire

Locality	Soil Association	Rate of erosion
Gwent	Milford	2.70

Shropshire	Salwick	4.33
	Bridgnorth	3.59
	Newport 1	3.31

Table 5 Distribution of values of erosion rates as predicted by MIRSED and as found in the field

Class values	Locality	
	Gwent	Shropshire
	% occurrence	% occurrence

	model	field	model	field
0-0.5 t ha^{-1} yr^{-1}	----	37.0	33.3	30.2
0.5-1.0 t ha^{-1} yr^{-1}	12.5	24.7	29.2	19.6
1.0-2.0 t ha^{-1} yr^{-1}	25.0	17.8	37.5	18.5
2.0-4.0 t ha^{-1} yr^{-1}	45.8	9.6	----	13.2
>4.0 t ha^{-1} yr^{-1}	16.7	11.0	----	18.5

Figures

1. Locations of monitored transects used for testing the MIRSED-WEPP model. 1- Cambridgeshire/Bedfordshire; 2 - Dorset; 3 - Gwent; 4 - Herefordshire; 5 - Kent; 6 - Norfolk East; 7- Notinghamshire; 8 - Shropshire; 9 - Somerset; 10 - Staffordshire; 11 - Sussex.

2. Predicted hillslope soil erosion from each of the 11 study sites. Grid cell size 1 km^2.

3. Air photo transects and 'core areas', Gwent and Shropshire, showing eroded fields.